micro-machine, for example. In another aspect, the invention concerns an exposure apparatus or a device manufacturing method using such a substrate attracting and holding system. --

Please substitute the paragraph beginning at page 2, line 4, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- One factor for causing degradation of the flatness of a wafer surface is the presence of a foreign particle caught between a chuck and a wafer. If a foreign particle of a few microns is once caught therebetween, the wafer at that portion is deformed and raised thereby. When the effective depth of focus is 1 micron or less, local defocus occurs there and, in a worst case, a pattern defect is produced. In order to avoid degradation of the product yield rate due to such foreign particles, based on the probability, pin contact chucks (pin chucks) wherein the contract rate between a chuck and a wafer is reduced to a minimum are used prevalently. --

Please substitute the paragraph beginning at page 2, line 17, and ending on page 3, line 12, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- As regards a machine for processing a substrate such as a semiconductor wafer, for semiconductor device manufacture, or a liquid crystal substrate, for liquid crystal display device manufacture, for example, a projection exposure apparatus, generally it uses a substrate attracting and holding system based on a vacuum attraction force to hold and secure a substrate (workpiece) and to correct any warp thereof to keep its flatness. Figure 31 shows an example of

such a substrate attracting and holding system. In the substrate attracting and holding system (chuck) 201 illustrated, a substrate carrying plane is defined by a carrying table which comprises a plurality of pin contact type protrusions 202 disposed in a grid and a peripheral rim type protrusion 203 provided at the peripheral portion of the carrying plane for supporting the peripheral portion of a substrate. Also, there are suction holes 205 formed at the carrying plane where the contact type protrusions are provided, which holes communicate with a vacuum piping system for reducing the pressure between the carrying plane and a substrate to be carried thereon. --

Please substitute the paragraph beginning at page 3, line 26, and ending on page 4, line 25, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- In the substrate attracting and holding system such as described above, the layout of the substrate supporting protrusions which provide the chuck carrying table is determined without any specific concern to the processing region on the substrate. It is set without any positional relationship with the substrate processing region. Namely, if the substrate processing region changes, the same chuck is used continuously. Therefore if the surface of a substrate is deformed as a result of the attraction and holding of the substrate, the deformation may cause not only a deformation of that portion of the substrate in a vertical direction but also a distortion along the plane of the substrate. Further, the layout of the substrate supporting protrusions of the chuck is determined without any specific concern to the layout of alignment marks of a substrate. If the

alignment mark layout of the substrate changes, the same chuck is used continuously. While a deformation of the substrate surface resulting from the attraction and holding of the substrate may cause an error in the coordinate of an alignment mark, since the relationship between each substrate alignment mark and each substrate supporting protrusion of the chuck is unknown, it is not possible to correct the coordinate error and, therefore, the registration precision is degraded. --

Please substitute the paragraph beginning at page 5, line 19, and ending on page 6, line 21, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- It is known that, in a pin chuck, a wafer is deformed and warped between pins of the chuck due to vacuum attraction and that this causes degradation of the flatness of the wafer surface. Many proposals have been made to solve this problem. For example, Japanese Patent No. 2574818 proposes a structure wherein a ring-like groove is formed in an outer peripheral portion of a chuck and wherein pins are provided in a central portion, inside the groove, at a pin pitch of 2 mm or less, so as to keep good wafer flatness at the chuck peripheral portion and good wafer flatness within the pin pitch at the chuck central portion. In this patent, it is stated that, with a pin chuck having pins disposed in a grid, the flatness within the pin pitch can be approximated by a model of a beam having both ends free-supported and that, from a desired flatness, a required pin pitch can be made to be 2m or less. However, the approximation with the beam having both ends free-supported means that the pin pitch as a whole is determined by using

the condition for the support with the free end at the outer peripheral portion, which condition is worse than that at the central portion. There is no disclosure about determining optimum pin pitches for the flatness at the outer peripheral portion and at the central portion respectively. Therefore, this causes an inconvenience that the pin pitch at the central portion becomes smaller than as required and, as a result, the contact rate becomes larger than as required. --

Please substitute the paragraph beginning at page 6, line 22, and ending on page 7, line 10, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- In an attempt to solve this problem, Japanese Patent No. 2821678 proposes a structure wherein the pin pitch at a central portion of a chuck is made larger than that at an outer peripheral portion of the chuck, thereby to improve the wafer flatness at the chuck outer peripheral portion and the chuck central portion while keeping the contact rate small. According to this proposal, it is suggested that the flatness within the pin pitch at the peripheral portion can be approximated with a model of a beam having one end fixed and another end free-supported, while the flatness within the pin pitch at the central portion can be approximated with a model of a beam having both ends fixed, and that the ratio between the pin pitches at the peripheral portion and the central portion can be optimized. --

Please substitute the paragraph beginning at page 7, line 22, and ending on page 8, line 25, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Although such wafer flatness, that is, degradation of the wafer surface flatness due to a warp produced within the pin pitch, is in fact a problem to be solved, there is a much more serious problem that a distortion (wafer distortion) is in practice produced due to the warp within the pin pitch. For example, when a wafer of a 200 mm diameter being currently widely used is placed on and attracted to a pin chuck having pins arrayed in a grid with a pin pitch of 2mm, there may occur a wafer distortion of about 1/2.6 of the wafer flatness. In a semiconductor process of 0.25 micron rule, being mass-produced currently, the tolerance for the wafer flatness is 80 nm if it is set to be 10% of a depth of focus 800 nm, whereas the tolerance for the wafer distortion is 5 nm if it is set to be 10% of an overlay precision of 50 nm. This value when converted into a wafer flatness becomes equal to 13 nm which is much smaller than 80 nm. Namely, it is seen that, as compared with the flatness as required by the depth of focus, the flatness as required by the overlay precision is much more strict. Conventionally, the flatness correction has been made so as to reduce the wafer flatness to a tolerance, whereas it has never been done so as to reduce the wafer distortion to a tolerance. As a result, the wafer distortion may be more than the tolerance, causing a degraded overly precision and a decreased yield rate. Alternatively, an additional process margin may be needed, which may obstruct further miniaturization of a semiconductor device or further enlargement of integration of it. --

Please substitute the paragraph beginning at page 8, line 26, and ending on page 9, line 17, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- In the aforementioned Japanese Patent No. 2821678, it is stated that, when the flatness at the outer peripheral portion of a wafer is made better, a positional deviation of an alignment mark at the wafer peripheral portion can be reduced like a positional deviation of an alignment mark at the wafer central portion. However, there is no quantitative statement about the alignment mark positional deviation. Further, there is no recognition of the inconvenience of a wafer distortion resulting from a warp within the pin pitch at the chuck central portion. There is no disclosure about determining an optimum relationship between the pin pitch and the attraction force, with respect to the wafer distortion. There is no disclosure about determining the relationship with respect to each of the peripheral portion and the central portion, respectively. Namely, there is no disclosure of reducing the wafer distortion to a tolerance. --

Please substitute the paragraph beginning at page 9, line 20, and ending on page 10, line 2, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- It is accordingly an object of the present invention to provide a substrate attracting and holding method, a substrate attracting and holding system, an exposure apparatus and/or a device manufacturing method using a substrate attracting and holding system, by which the influence, upon a substrate processing precision, of an error, in the coordinates of an alignment mark to be

produced by deformation of the surface of the substrate resulting from the attraction and holding of the substrate, is reduced. --

Please substitute the paragraph beginning at page 10, line 12, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- It is another object of the present invention to provide a substrate attracting and holding system, an exposure apparatus and/or a device manufacturing method using a substrate attracting and holding system, by which a distortion or degradation of a flatness of the surface of a substrate such as a wafer, for example, due to deformation of the substrate surface to be produced when the substrate is attracted and held by using a plurality of protrusions, can be reduced so that the substrate can be attracted and held in an optimum state and that an overlay precision can be improved. --

Please substitute the paragraph beginning at page 14, line 18, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Figure 15 is a schematic view for explaining bending moments and flexure curves in the double-end fixed beam of Figure 14. --

Please substitute the paragraph beginning at page 16, line 20, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Figure 31 is a plan view of a substrate attracting and holding system of a known type. --

Please substitute the paragraph beginning at page 17, line 11, and ending on page 18, line 6, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Denoted in Figure 1A at 1 is a chuck which comprises a substrate attracting and holding system to be mounted on a chuck stage of a semiconductor exposure apparatus, for example. In Figure 1B, denoted at 100 is a substrate such as a wafer to be attracted and held by the chuck 1. Denoted at 101 is a region (shot) of the substrate 100 which region is to be processed by a single operation. Alternatively, it denotes boundaries (scribe lines) for defining each semiconductor chip (die). As regards alignment marks of the substrate 100, alignment marks are already formed at positions as depicted by crosses 10 and triangles 11. Alternatively, alignment marks are going to be produced at these positions. At each position of the cross 10, there is an alignment mark 12 (Figure 1C) which is a mark for position measurement with respect to the X direction. At each position of the triangle 11, there is an alignment mark 13 which is a mark for position measurement with respect to the Y direction. Here, an alignment mark may be an alignment mark having already been provided on a substrate, or it may be an alignment mark to be produced on the substrate for the subsequent process. --

Please substitute the paragraph beginning at page 18, line 7, and ending on page 19, line 17, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- In the chuck 1 of Figure 1A, there are protrusions which provide a carrying table for carrying a substrate 100 thereon and which support the substrate thereon. The protrusions include rim type protrusions 2a each comprising a rim-like protrusion having its top surface finished with a high flatness and a vacuum suction groove formed at the center of the width of the top thereof. In this embodiment, these protrusions are disposed along the scribe lines 101 of the shots on the substrate 100, and thus about the scribe lines 101. With the layout of the rim type protrusions 2a as described above, when the substrate 100 is attracted and held by the chuck 1, alignment marks of the substrate can be constantly placed above the protrusions 2a. Denoted at 3 is a ring-like protrusion being provided at an outer peripheral portion of the chuck 1. It comprises a rim-like protrusion and a vacuum suction groove. Denoted at 4 is a region between the ring-like protrusion 3 and the protrusions 2a. In the region 4, substrate supporting protrusions and a vacuum suction groove may be provided, as required. Denoted at 4 are suction holes which are communicated with a vacuum suction unit 8 (Figure 2) for holding a substrate by attraction. These holes are formed to be communicated with suction grooves of the protrusions 2a and 3, respectively. Denoted at 5 are opening bores for adjusting a gas pressure in a space between the chuck 1 and the substrate 100 as attracted and held by the chuck 1. Each of these bores 6 is formed in a zone as divided by the protrusions 2a, that is, in a portion inside a shot of the substrate 100. As shown in Figure 2, these bores 6 are communicated with a pressure

adjusting unit 7. Further, the protrusions 2a and 3 of the carrying table for supporting the substrate 100 may preferably be arranged so that the total area contacting the substrate 100 is 10% or less of the area of the substrate surface. --

Please substitute the paragraph beginning at page 20, line 2, and ending on page 21, line 16, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- As described above, when the substrate 100 is held by vacuum attraction while being aligned with the chuck 1 as in this embodiment, the scribe line 101 portion of the substrate is attracted and secured by the vacuum suction grooves provided at the protrusions 2a, disposed along the scribe lines 101 of the shots of the substrate 100. As a result of it, as shown in Figure 2, a flexure deformation is caused at the surface of the substrate 100. Such deformation of the substrate surface also causes distortion of the substrate along a horizontal plane. Namely, due to such horizontal distortion, in each shot there arise errors in coordinates as a result of deformation of the substrate surface, such as shown in Figure 3, for example. In Figure 3, each shot depicts a position inside a shot on the substrate, and the length of each line represents the magnitude of the coordinate error in the position of that dot. Since these coordinate errors in each shot are determined by the amount of inclination of the substrate surface, the coordinate error is small in a portion where the tilt of the substrate surface is small, near horizontal. In Figure 2, at the scribe line 101 portion as denoted at 21 and at the central portion of a shot as denoted by 22, and coordinate error is small (in Figure 3, the portion corresponding to the scribe line 101 portion at

21 is not illustrated). Therefore, if the alignment marks 12 and 13 of the substrate 100 are provided inside a shot (except the scribe line), then they are largely influenced by the coordinate errors such as shown in Figure 3. In this embodiment, however, the alignment marks of the substrate are disposed inside the scribe line 101. This portion of the substrate corresponds to the position shown at 21 in Figure 2, and it is supported by the rim type protrusions 2a having a vacuum suction groove. As a result, the position where an alignment mark is present is held substantially horizontal and, therefore, the alignment mark can be maintained substantially without being influenced by the coordinate error caused by the attraction and holding of the substrate. --

Please substitute the paragraph beginning at page 21, line 17, and ending on page 22, line 9, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Even in cases where the procedure for the substrate processing advances and changing the alignment mark forming position becomes necessary, the same advantageous results are attainable by selection of any position, as long as it is inside the scribe line. Further, in this embodiment, the central portion of the shot corresponds to the position shown at 22 in Figure 2, and it is the position not influenced by the coordinate error resulting from the deformation of the substrate surface by the substrate attraction. Therefore, an alignment mark can be formed there. Furthermore, by adjusting the gas pressure in the space between the chuck 1 and the substrate 100 through the function of the pressure adjusting unit 7, the region not influenced by the

coordinate error as denoted at 22 in Figure 2 can be extended. Thus, the region without being influenced by the coordinate error can be extended as required, such that the region for placement of alignment marks can be enlarged. --

Please substitute the paragraph beginning at page 22, line 10, and ending on page 23, line 6, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- The alignment mark 12 shown in Figure 1C is a mark for position detection with respect to the X direction. The necessary condition for the location of the mark to avoid the influence of the coordinate error resulting from deformation of the substrate surface, is that the substrate surface has no inclination at least in the X direction. Any inclination in the Y direction does not affect the position detection in the X direction. Similarly, the alignment mark 13 shown in Figure 1C is a mark for position detection with respect to the Y direction. The necessary condition for the location of the mark to avoid the influence of the coordinate error resulting from deformation of the substrate surface, is that the substrate surface has no inclination at least in the Y direction. Any inclination in the X direction does not affect the position detection with respect to the Y direction. In consideration of the above, in this embodiment, a mark for position detection in the X direction may preferably be provided in a scribe line which is substantially parallel to the X direction, while a mark for position detection in the Y direction may preferably be provided on a scribe line which is substantially parallel to the Y direction. --

Please substitute the paragraph beginning at page 25, line 18, and ending on page 26, line 22, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Further, in the embodiment of Figure 4, there are alignment marks provided on the chuck 1, for bringing the chuck 1 and the substrate 100 into a particular positional relationship. More specifically, in a portion of the chuck 1 not to be covered by a substrate 100 as the same is attracted and held by the chuck, for example, at zones 9, plural sets of alignment marks such as at 12 and 13 in Figure 1C may be provided. Like the preceding embodiment, the substrate 100 may be provided with alignment marks 12 (Figure 1C) at positions of crosses 10, and alignment marks 13 (Figure 1C) at positions of triangles 11. The positional relation between the chuck 1 and the substrate 100 held by the chuck 1 may be measured by using an alignment scope 108 (see Figure 8) and a chuck stage 107 (Figure 8) of an exposure apparatus, and the positional relation between them may be adjusted by using a driving mechanism (not shown). Thereafter, the substrate 100 may be held fixed. With this procedure, the alignment mark layout on the substrate and the protrusion layout of the chuck can be brought into a particular positional relationship such as, for example, placing each alignment mark of the substrate at the center of the layout of the pin contact type protrusions 2b of the chuck 1. The alignment marks may be those generally used for registration of a projected image of a reticle with a substrate. Since exposure apparatuses are usually equipped with the function of an alignment scope, advantageously there is no necessity of adding a special function to the exposure apparatus. --

Please substitute the paragraph beginning at page 26, line 25, and ending on page 27, line 21, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Figure 5 shows a substrate attracting and holding system according to another embodiment of the present invention. This embodiment is an example wherein the protrusion for supporting a substrate is not provided with a vacuum suction groove. As regards the protrusion, this embodiment uses pin contact type protrusions 2b like those of the embodiment of Figure 4. Further, the suction holes 5 communicated with a vacuum suction unit in the Figure 4 embodiment are formed as opening bores 6 being communicated with a pressure adjusting unit 7. In this embodiment, with this pressure adjusting unit 7, the gas pressure in the space between the chuck 1 and the substrate 100 is adjusted at a negative pressure side, relative to the pressure at the top face of the substrate, whereby a substrate attracting function is provided also with this adjustment. Substantially the same advantageous results as those of the embodiment of Figure 2 are attainable with this structure. Further, in the embodiments of Figures 2 and 5, the structure may be modified so that different pressure adjustments are performed to the opening bores 5 opposed to the substrate 100. This meets substrates having a warp as a whole or a large focal flexure, for example. --

Please substitute the paragraph beginning at page 30, line 7, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- With the structure of this embodiment as described above, even in a case where

alignment marks of the substrate are formed outside the shot layout, when the substrate 100 is attracted and held by the chuck 1, the portion surrounding the alignment mark forming positions 10 and 11 of the substrate is supported by the pin contact type protrusions 2b(o) arrayed in an oblong shape. Further, the alignment mark forming positions 10 and 11 are placed in such a positional relationship with the pin contact type protrusions 2b(o) of oblong shape array that they are located at a place where no coordinate error occurs. Therefore, the influence of deformation of the substrate surface such as warp caused by attraction and holding of the substrate can be avoided. The coordinate error of the alignment mark can be reduced, and degradation of the substrate processing precision or registration precision can be prevented. --

Please substitute the paragraph beginning at page 30, line 25, and ending on page 31, line 21, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- As long as the alignment mark forming position on the substrate is placed at a location equivalent to the position 22 in Figure 2 relative to the substrate supporting protrusions as the substrate is attracted and held thereby, the substrate supporting protrusions are not limited to the pin contact type protrusion and they may be provided by a rim type protrusion or protrusions. Further, the shape of the array of the substrate supporting protrusions surrounding the alignment mark forming position is not limited to an oblong shape. It may have a triangular shape, a polygonal shape or an elliptical shape. Further, a substrate supporting protrusion may be provided at a portion corresponding to the alignment mark forming position outside the shot

layout of the substrate, so that the alignment mark forming position of the substrate is supported by this supporting protrusion. This enables that the alignment mark forming position is supported substantially horizontally, like the position 21 shown in Figure 2, thereby to remove the coordinate error of the alignment mark. On that occasion, similarly, degradation of the substrate processing precision and registration precision can be prevented. --

Please substitute the paragraph beginning at page 35, line 16, and ending on page 36, line 2, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- In the embodiments as described above, the position of an alignment mark or the position where an alignment mark is to be formed and a protrusion layout adjacent to that position are placed in a particular positional relationship with each other. More specifically, the positions of alignment marks of the substrate or the positions where alignment marks are going to be produced are set at such a location less influenced by deformation of the substrate surface resulting from the attraction and holding of the substrate. This effectively reduces the coordinate error of the alignment mark resulting from the deformation of the substrate surface. --

Please substitute the paragraph beginning at page 38, line 22, and ending on page 39, line 16, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- With the structure of the exposure apparatus as described above, an error in the coordinate of an alignment mark to be produced by deformation of the substrate surface attributable to the attraction and holding of the substrate can be calculated once the combination of the alignment mark forming position inside the substrate and the disposition of the protrusions of the chuck is determined. Therefore, even if the alignment mark position cannot be set exactly at the location as described with reference to the preceding embodiments, the coordinate error of the alignment mark can be calculated by the control unit 12 on the basis of the combination of the alignment mark disposition on the substrate and the disposition of the substrate supporting protrusions of the chuck. By taking the result of calculation into account with respect to the result of detection of the alignment mark through the alignment scope 108, the magnification or distortion of the projection optical system 111 can be adjusted to assure optimum superposition of a projected image of the reticle 103 with the pattern of the substrate 100. --

Please substitute the paragraph beginning at page 39, line 17, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- A tolerance of alignment for an alignment mark of a substrate with the disposition of protrusions of a chuck for supporting the substrate can be estimated by approximation using a model such as follows. Figure 9 shows flexure of a substrate as attracted to and held by the protrusions. Figure 9B shows a model of a beam having both ends fixed, which receives an evenly distributed load. Figure 9C is a view for explaining the relation between the substrate surface and a neutral plane not deformed by the flexure of the substrate. --

Please substitute the paragraph beginning at page 40, line 1, and ending on page 42, line 5, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- When the spacing between protrusions 2 for supporting the substrate is 1, the flexure of the substrate is such as shown in Figure 9A. In this case, as regards a material dynamic model, a model of a beam having both ends fixed and receiving an evenly distributed load such as shown in Figure 9B applies. According to "Mechanical Engineering Handbook", edited by Japanese Mechanical Engineering Association, Maruzen Co., if a load per a unit length as determined by a vacuum pressure p or the like is w, a sectional secondary moment is I, the spacing between the protrusions is 1, and a longitudinal elasticity coefficient is E, then the flexure v of the substrate at a position x with respect to a direction from a protrusion end as an origin to a juxtaposed protrusion as well as the inclination i of the substrate are expressed as follows:

$$v = (w1^4/24EI)[x^2/1^2-2x^3/1^3+x^4/1^4] \qquad ...(1.1)$$

$$i = (w1^3/12EI)[x/1-3x^2/1^2+2x^3/1^3] \qquad ...(1.2)$$

Here, when a thickness h of the substrate and a width b thereof shown in Figure 9B are used, it follows that there are relations such as follows:

$$I = bh^3/12 \qquad ...(1.3)$$

$$w = pb \qquad ...(1.4)$$

In Figure 9C, a dash-and-dot line passing about the center of the thickness h depicts a neutral plane which is not elongated or contracted in the X direction, at any position thereof. With respect to this neutral plane, depending on the location, there occurs an elongation/contraction in

the X direction of the substrate surface. Since the distance from the neutral plane to the substrate surface is influenced by the processing state of the substrate or the attraction state thereof, taking k as a neutral plane correction coefficient, the coordinate error d of the substrate surface can be expressed as follows:

$$d = k(hi/2) = k(hw1^3/24EI)\,[x/1-3x^2/1^2+2x^3/1^3] \qquad ...(1.5)$$

From this, it follows that:

$$d = f(x) = k(pl^3/2h^2E)[x/1-3x^2/1^2+2x^3/1^3] \qquad ...(1.6)$$

The tolerance for the alignment error (i.e., the difference between the value x in an idealistic state and the value x_a being shifted practically) between the disposition of the alignment mark of the substrate and the disposition of the protrusion of the chuck, if a tolerance for the coordinate error not adversely influential to the alignment is set, can be detected from equation (1.6) above, since the values p, h, E and I are known as determined by the apparatus or the substrate to be used in practice. If the tolerance for the coordinate error is denoted by d_c, then the alignment error tolerance x_c can be determined to satisfy equation (1.7) below:

$$d_c \geq f(x_c)-f(x_0) \qquad ...(1.7)$$

Practically, while the two-dimensional disposition of the protrusions is taken into account, equation (1.6) as the same is advanced may be used, with a result of high accuracy. --

Please substitute the paragraph beginning at page 44, line 2, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- In accordance with the present invention as described hereinbefore, the position of an alignment mark of a substrate or the position where an alignment mark is going to be formed can be set at a specific location in relation to flexure of a substrate to be attracted and held, to thereby avoid an adverse influence of a coordinate error of the alignment error due to flexure of the substrate surface. Further, the coordinate error of the alignment mark can be calculated beforehand from the positional relationship between the alignment mark and the disposition of a protrusion for supporting the substrate adjacent there. On the basis of the result of calculation, the coordinate error of the alignment mark can be corrected. --

Please substitute the paragraph beginning at page 45, line 20, and ending on page 46, line 4, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- The pin-like protrusions 310 shown in Figures 11A and 11B have a pin diameter of 0.2 mm, and they are juxtaposed in a grid-like array with a disposition pitch of L mm. There is at least one suction hole 311 for vacuum attraction, at the top face of the chuck, which is communicated with a vacuum source. In place of the grid-like disposition of the pin-like protrusions 310, they may be arrayed concentrically as shown in Figure 12. They may be disposed in a 60-degree staggering array, or they may be disposed at random with a pin pitch of L mm or less. An array based on a combination of those described above may be used. --

Please substitute the paragraph beginning at page 47, line 16, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Figure 13 is a sectional view showing the flexure at the portion of a wafer 302 where, in the central portion of the chuck 301, there are pin-like protrusions 310 juxtaposed continuously along one direction with a pin pitch L, when the wafer is attracted and held thereby. In this example, as regards a material dynamics model, a model of a beam having its opposite ends fixed and receiving an evenly distributed load, as shown in Figure 14, applies. --

Please substitute the paragraph beginning at page 47, line 25, and ending on page 48, line 17, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Here, if the width of the beam is b, the thickness thereof is h, and the sectional secondary moment is I, it follows that:

$$I = (b \bullet h^3)/12 \quad \text{...(2.1)}$$

If the vacuum pressure is p and the load per a unit length is w, it follows that:

$$w = p \bullet b \quad \text{...(2.2)}$$

When the length of the beam is L and the longitudinal elasticity coefficient is E, the maximum flexure amount v of the beam is given by:

$$v = (w \bullet L^4)/(384 \bullet E \bullet I) \quad \text{...(2.3)}$$

By modifying equation (2.3) by using equations (2.1) and (2.2), it follows that:

$$v = (P \bullet L^4)/(32 \bullet E \bullet h^3) \quad \text{...(2.4)}$$

Namely, this means that the largest flexure amount v of the beam is not dependent upon the width b but, rather, it is determined by the vacuum pressure p, the beam length L, the longitudinal elasticity coefficient E and the thickness h. Then, the largest flexure amount v corresponds to the wafer flatness. --

Please substitute the paragraph beginning at page 48, line 18, and ending on page 49, line 7, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Next, when the coordinate of the beam in its lengthwise direction is x and the bending moment is M, it follows that:

$$M = (w \bullet L^2/2)[-1/6+x/L-x^2/L^2] \qquad \text{...(2.5)}$$

Figure 15 shows the relation (curve 15) between the coordinate x and the moment M as well as the flexure curve (curve 16) of the beam. As seen also from Figure 15, the moment M is negative in ranges a and c of the coordinate x, whereas it is positive in a range b. Also, at two positions x1 and x2 where M becomes equal to zero, the tilt angle of the beam flexure curve becomes largest. When this largest tilt angle is denoted by α, it follows that:

$$\alpha = (\sqrt{3w} \cdot L^3 / 216 \cdot E \cdot I) \qquad \text{...(2.6)}$$

When this is modified by using equations (2.1) and (2.2), it follows that:

$$\alpha = (\sqrt{3} \cdot P \cdot L^3) / (18 \cdot E \cdot h^3) \qquad \text{...(2.7) --}$$

Please substitute the paragraph beginning at page 49, line 12, and ending on page 51, line 5, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Since, in practice, a wafer has a thickness h, if it is illustrated with exaggeration, the result is such as shown in Figure 16. In Figure 16, a dash-and-dot line 17 passing through the middle of the thickness h depicts a neutral plane at any position on which there occurs no elongation or contraction. At a side of the neutral plane facing the wafer surface, due to the bending moment M, there occurs an elongation, by tension, in the X direction within the ranges a and c of the coordinates x. In the range b, there occurs a contraction in the X direction, by compression. On the other hand, at a side of the neutral plane facing the wafer bottom surface, there occurs a concentration, by compression in the ranges a and c of the coordinate x, while there occurs an elongation in the X direction, by tension, in the range b. The amount of elongation or contraction in the X direction is proportional to the distance from the neutral plane and also, it is proportional to the tilt angle of the neutral plane. Namely, a positional deviation to be produced by the elongation/contraction of the wafer surface in the X direction resulting from the attraction becomes equal to zero at the positions x3, x5 and x7 where the tilt angle is zero, whereas it becomes largest at the positions x4 and x6 where the tilt angle is maximum. As rgards the distance from the neutral plane to the wafer surface, in a case of a monocrystal Si wafer, it may be approximately equal to h/2. However, it may differ from h/2, depending on the material or uniformness of the wafer or the substrate, the process or processes having been applied to the surface or bottom surface, or the state of attraction to the chuck, for example. Thus, by taking it

as k•h/2 wherein k is the neutral plane correction coefficient and if the largest positional deviation is denoted by u, it follows that:

$$u = [(h \cdot \alpha)/2] \cdot k \qquad ...(2.8)$$

When this is modified by using equation (2.7), it follows that:

$$u = [\sqrt{3} \cdot P \cdot L^3) / (36 \cdot E \cdot h^2)] \cdot k \qquad ...(2.9)$$

Namely, this means that the largest positional deviation amount u on the wafer surface is not dependent upon the width b but, rather, it is determined by the neutral plane correction coefficient k, the vacuum pressure p, the beam length L, the longitudinal elasticity coefficient E and the thickness h. Since the exposure process is performed in this state, the image to be printed on the wafer is an image being distorted relative to the wafer by an amount corresponding to the positional deviation. Therefore, the largest positional deviation u corresponds to the wafer distortion. --

Please substitute the paragraph beginning at page 51, line 6, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- While the explanation above has been made to a one-dimensional beam model with respect to the portion where the pin-like protrusions 310 are juxtaposed continuously along one direction with a pin pitch L, practically, the pin array comprises a two-dimensional array. Depending on the disposition used, such as grid-like disposition, circumferential disposition, 60-degree staggering disposition, random disposition or the like, the values of the largest flexure

amount v and the largest positional deviation u are variable. In consideration of it, when the wafer flatness as a flat wafer is attracted in practice as V_1, the wafer distortion is U_1 and the correction coefficients depending on the pin disposition are c_1 and c_2, it follows that:

$$V_1 = v \cdot c_1 = [(P \cdot L^4) / 32 \cdot E \cdot h^3)] \cdot c_1 \qquad ...(2.10)$$

$$U_1 = u \cdot c_2 = [(\sqrt{3} \cdot P \cdot L^3) / (36 \cdot E \cdot h^2)] \cdot k \cdot c_2 \qquad ...(2.11) \text{ --}$$

Please substitute the paragraph beginning at page 51, line 23, and ending on page 52, line 15, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- In the case of grid-like disposition, as shown in Figure 17, since the largest flexure occurs at the position of the center 318 of four pins 319 - 323, it can be regarded that the flexure becomes larger than that of a case where a beam 323 supported by the pins 319 and 323 is considered and the flexure is calculated while taking the length as L, and also that it becomes smaller than that in a case where a beam 324 as supported by diagonal protrusions 319 and 321, of the four pins, is considered and the flexure is calculated while taking the length as $L \cdot 2^{1/2}$. Therefore, it can be regarded that the correction coefficient c_1 becomes equal to 1 to 4 ($=2^{1/2, 4}$) while the correction coefficient c_2 becomes equal to 1 to 2.8 ($= 2^{1/2, 3}$). Since, however, the beam 324 supported by the diagonal pins 319 and 321 and the beam 325 supported by the diagonal pins 320 and 322 may be flexed independently, by the same amount, the value may be close to that as determined while taking the beam length as $L \cdot 2^{1/2}$. --

Please substitute the paragraph beginning at page 57, line 12, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Although equation (2.17) has been determined with reference to a Si wafer of a diameter 200 mm, having a thickness h = 0.725 mm, a Si wafer of a diameter 125 mm may have a thickness h = 0.725 mm and, on that occasion, it follows that:

$$P \leq 0.00245/L^3 \qquad ...(2.21)$$

Thus, in Figure 25, the range corresponds to a lower left zone below a solid line 343. --

Please substitute the paragraph beginning at page 57, line 20, and ending on page 58, line 2, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Further, for a Si wafer of 300 mm diameter, the thickness is h = 0.775 mm. Also it is expected that wafers of a larger diameter such as 400 mm Si wafers are used in the future. The thickness will become h = about 0.825 mm. In consideration of this, the value is calculated with a thickness h =0.825 mm. The, it follows that:

$$P \leq 0.00427/L^3 \qquad ...(2.22)$$

In Figure 25, it corresponds to a lower left zone below a solid line 341. --

Please substitute the paragraph beginning at page 58, line 3, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Further, with further miniaturization of a semiconductor device, the semiconductor process will change to 0.18 micron rule, 0.13 micron rule or to 0.1 micron rule. With these changes, improvements in the overlay precision are absolutely required. Thus, it is expected that the tolerance for wafer distortion is changed to a much stricter value, such as from 5 nm to 2.5 nm and to 1 nm. --

Please substitute the paragraph beginning at page 59, line 21, and ending on page 60, line 14, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- As described above, the practical range for the vacuum pressure P and the pin pitch L at the wafer central portion has been considered in accordance with equation (2.15) and with respect to various values of the wafer thickness h and the wafer distortion tolerance dxdy. In these examples, since the range of the pin pitch L as determined by equation (2.16) satisfies a standard pin pitch (not greater than 5 mm) to be described later, the condition of equation (2.14) is also satisfied. This is because, even in a case where the right side of equation (2.16) becomes smallest, that is, even in the case of a smallest thickness h = 0.625 mm and a largest dxdy = 5 nm, a relation $L \leq 0.011$ is given such that the standard pin pitch 5 mm to be described later is satisfied. Therefore, by arranging the chuck with a vacuum pressure P and a pin pitch L, at the wafer central portion, which are selected out of the range described above, a desired wafer flatness tolerance dz and a desired wafer distortion tolerance dxdy can be satisfied. --

Please substitute the paragraph beginning at page 61, line 14, and ending on page 62, line 25, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- On the other hand, an ordinary range for the pin pitch L of the chuck will be, under different conditions of the chuck, as follows. The smallest pin pitch L which can be used in practice is determined by the contact rate between the chuck and the wafer. Therefore, the relation between the pin pitch and the contact rate will be described first. If the number of pins per unit areas is n, since in the grid-like disposition shown in Figure 7, there is one pin in the area as enclosed by the centers of the four pins 319 - 232, it follows that:

$$n = 1/L^2 \qquad \text{...(2.33)}$$

Further, in the case of the 60-degree staggering disposition shown in Figure 18, there is one pin in the area as enclosed by four pins 327 - 330, it follows that:

$$n = (2/3^{1/2})/L^3 \qquad \text{...(2.34)}$$

Further, when the area at the free end of each pin is denoted by s and the wafer-to-pin contact rate is denoted by N, since $N = s \cdot n$, it follows that:

In the case of grid-like disposition:

$$N = s/L^2 \qquad \text{...(2.35)}$$

In the case of 60-degree staggering disposition:

$$N = (2/3^{1/2}) \cdot s/L^2 \qquad \text{...(2.36)}$$

Therefore, the wafer-to-pin contact rate N is determined by the area s at the free end face of the pin and the pin pitch L. According to experiences of semiconductor processes, the practical

contact rate N is about 0.008 in a case where the pin pitch L is about 2 mm, and the pin free end face has a diameter 0.2 mm, namely, the area s of the free end face of the pin is $s = \pi \cdot (0.1)^2 = 0.0314\ mm^2$. Thus, by machining the pin free end face to a diameter of about 0.05 mm, the pin pitch L can be reduced to 0.5 mm while keeping the contact rate of substantially the same level. Thus, it follows that:

$$L \geq 0.0005 \qquad \text{...(2.37)}$$

In Figure 25, it corresponds to a right-hand side zone of a solid line 352. --

Please substitute the paragraph beginning at page 62, line 26, and ending on page 63, line 25, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Next, the largest pin pitch L which can be used in practice is determined by the periodicity of a local warp of the wafer. In practice, a wafer has various warps of different periodicities, such as those from a global warp extending throughout the wafer to a warp having a very fine periodicity. It is an important function of a wafer chuck to correct these warps to accomplish the flatness. However, a pin chuck, is, in principle, unable to correct a warp having a periodicity smaller than the pin pitch. Namely, it is necessary to make the pin pitch smaller than the smallest periodicity of a warp, of an amplitude of about 13 nm, which may have an adverse influence as a wafer distortion. In order to accomplish a positive correction effect, a pin pitch not greater than a half of the smallest periodicity has to be used. As regards the periodicity of a wafer warp, while details are not known because of difficulties in separation from the thickness

non-uniformness or of the measuring precision, it should be expected that a warp of a period of about 10 mm at the largest may remain though the wafer warp may be improved in the future. In consideration of it, the pin pitch should desirably be set to be 5 mm or less.

$$L \leq 0.005 \qquad \text{...(2.38)}$$

In Figure 25, it corresponds to a zone on the left-hand side of a solid line 353. --

Please substitute the paragraph beginning at page 64, line 8, and ending on page 65, line 1, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- While the foregoing description has been made with reference to the portion where the pin-like protrusions 310 are juxtaposed continuously along one direction with a pin pitch L, that is, the central portion of the chuck inside the outer peripheral portion thereof, a description will now be made of the outer peripheral portion of the chuck. Figure 19 is a sectional view for explaining flexure of a wafer 2 as attracted and held by the outer peripheral portion of the chuck. In this drawing, the partition wall 312 is provided just inside the outermost circumferential protrusion 313, and the height of the partition wall 312 is made lower than the top face of the protrusion 313 by about 1 - 2 microns. This is because, with a gap of about 1 - 2 microns, a decrease of vacuum pressure for attraction is so small that it causes no problem. On the other hand, even if a dust particle of a diameter smaller than the difference of 1 - 2 microns is adhered to the partition wall 312, it does not contact the substrate. Thus, it does not cause an increase of the contact rate.

Please substitute the paragraph beginning at page 65, line 2, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- As regards a material dynamics model for the state of flexure of a wafer at the outer peripheral portion of the chuck, a model of a beam having a fixed end and another free end and receiving an evenly distributed load, as shown in Figure 20, applies. However, the outermost circumferential pin 313 supports a wafer 302 with its corner, not the center of the pin, as shown in Figure 19. The pin pitch L is this case is the distance from the inside corncer of the pin 313 to the pin 314 which is located inside thereof by one pitch. --

Please substitute the paragraph beginning at page 65, line 13, and ending on page 66, line 2, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- When the maximum flexure amount is denoted by v, it is expressed as follows:

$$v = (w \cdot L^4)/(184.6 \cdot E \cdot I) \qquad \text{...(2.40)}$$

By modifying this equation by using equations (2.1) and (2.2), it follows that:

$$v = (P \cdot L^4)/(15.38 \cdot E \cdot h^3) \qquad \text{...(2.41)}$$

Also, the tilt angle of the beam flexure curve becomes largest at the supporting position of the outermost pin 313. If this largest title angle is denoted by α, it follows that:

$$\alpha = (w \cdot L^3)/(48 \cdot E \cdot I) \qquad \text{...(2.42)}$$

When this is modified by using equations (2.1) and (2.2), it follows that:

$\alpha = (P \cdot L^3)/(4 \cdot E \cdot h^3)$ ...(2.43)

Thus, from equation (2.8), the largest positional deviation u is given as follows:

$u = [(P \cdot L^3)/(8 \cdot E \cdot h^2)] \cdot k$ ...(2.44) --

Please substitute the paragraph beginning at page 66, line 3, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Therefore, when the wafer flatness as a flat wafer is attracted in practice is V_2, the wafer distortion is U_2 and the correction coefficients depending on the pin dispositions, like those of the wafer central portion, are c_1 and c_2, it follows that:

$V_2 = v \cdot c_1 = [(P \cdot L^4)/15.38 \cdot E \cdot h^3)] \cdot c_1$ ...(2.45)

$U_2 = u \cdot c_2 = [(P \cdot L^3)/(8 \cdot E \cdot h^2)] \cdot k \cdot c_2$ ...(2.46) --

Please substitute the paragraph beginning at page 67, line 14, and ending on page 68, line 1, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Thus, now a case wherein a typical Si wafer of a diameter 200 mm is attracted and held by a pin chuck having a grid-like pin disposition is considered, like the example of the wafer central portion described hereinbefore. It is taken that the longitudinal elasticity coefficient $E = 1.69 \times 10^{11}$ N/m, th thickness h = 0.725 mm, the neutral plane correction coefficient k = 1, and the correction coefficients $c_1 = 4$ and $c_2 = 2.8$. Also, in a semiconductor process of 0.25 micron rule,

the wafer flatness tolerance dxdy is 5 nm. Then, while taking the unit of pressure P as N/m^2 and the unit of pitch L is m, from equations (2.50), it follows that:

$$P \leq 0.0127/L^3 \qquad \text{...(2.52) --}$$

Please substitute the paragraph beginning at page 69, line 24, and ending on page 70, line 17, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- As described above, the practical range for the vacuum pressure P and the pin pitch L at the wafer outer peripheral portion has been considered in accordance with equation (2.5) and with respect to various values of the wafer thickness h and the wafer distortion tolerance dxdy. In these examples, since the range of the pin pitch L as determined by equation (2.51) satisfies a standard pin pitch (not greater than 5 mm) to be described later, the condition of equation (2.49) is also satisfied. This is because, even in a case where the right side of equation (2.51) becomes smallest, that is, even in the case of a smallest thickness h = 0.625 mm and a largest dxdy = 5 nm, a relation $L \leq 0.013$ is given such that the standard pin pitch 5 mm to be described later is satisfied. Therefore, by arranging the chuck with a vacuum pressure P and a pin pitch L, also at the wafer outer peripheral portion, which are selected out of the range described above, a desired wafer flatness tolerance dz and a desired wafer distortion tolerance dxdy can be satisfied. --

Please substitute the paragraph beginning at page 71, line 18, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- As described above, because the wafer central portion and the wafer peripheral portion are different with respect to the manner of supporting the wafer, the chuck may be structured to have respective vacuum pressures P and respective pin pitches L selected out of the ranges described hereinbefore, by which a desired wafer flatness tolerance dz and a desired wafer distortion tolerance dxdy can be satisfied throughout the whole wafer surface. --

Please substitute the paragraph beginning at page 71, line 27, and ending on page 72, line 24, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- At the wafer central portion and the wafer peripheral portion, a common vacuum pressure P and/or a common pitch L may be set, within the ranges described hereinbefore. Alternatively, they may be set independently of each other. When vacuum pressures P should be set independently of each other, in addition to the outermost peripheral partition wall 312, a continuous inside partition wall may be provided so as to connect all the pins 314 disposed circumferentially inside the outermost pins 313 by one pitch, and vacuum suction opening bores may be formed in the wafer central portion and the wafer peripheral portion of the chuck such that vacuum pressures can be supplied to them independently. Further, as regards the inner partition wall, a ring-like partition wall 334 (Figure 21) may be provided with a small inward shift from the pin 314. This facilitates formation of a step at the inner partition wall 334. The height of the inner partition wall should preferably be made lower than the top face of the pin 314 by 1 - 2 microns. This is because, in that structure, it does not contact a wafer even if the

same is warped. Also, if a dust particle of a diameter smaller than that spacing is adhered, it does not contact the wafer. The contact rate is not raised. --

Please substitute the paragraph beginning at page 72, line 25, and ending on page 73, line 10, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- When the height of the inner partition wall is made lower than the top face of the pin 314 and a vacuum pressure is supplied only to the wafer central portion, the vacuum pressure at the wafer peripheral portion can be made lower than that at the wafer central portion. Alternatively, an opening bore being communicated with the atmosphere may be formed in the wafer central portion, and a vacuum pressure may be supplied only to the wafer peripheral portion. On that occasion, the vacuum pressure at the wafer peripheral portion can be held higher than that at the wafer central portion. In this case, only a single vacuum supplying line is necessary.

Please substitute the paragraph beginning at page 73, line 11, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- While the outermost partition wall 312 is disposed with a slight inward shift from the pins 313 as shown in Figure 19 or 21, it may be provided outside the pins 313. Alternatively, a continuous partition wall for connecting all the pins 313 may be provided so as to surround the chuck peripheral portion. As a further alternative, while the contact rate becomes larger, the pins

313 may be omitted and, in place thereof, an outermost partition wall of the same height as the top face of the pins 313 may be provided. --

Please substitute the paragraph beginning at page 74, line 25, and ending on page 76, line 1, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- The vacuum pressure at the peripheral portion may be set appropriately lower than that at the wafer central portion and the pin pitch may be made properly narrow. This enables setting the same distortion amount at the wafer central portion and the peripheral portion and, additionally, it leads to enlargement of the range in which their distribution shapes are approximately registered. Details will be explained with reference to Figures 27A and 27B. Figure 27A shows a flexure curve of a wafer between the pin pitch. The axis of ordinate shows the flexure amount v. Figure 27B shows the shape of distribution of wafer distortion between the pin pitch. The axis of ordinate shows the wafer distortion u. In Figures 27A and 27B, the axis of abscissa depicts the wafer position x between or inside the pin pitch, with the rightward direction corresponding to the wafer outward direction. In Figure 27A, denoted at 380 is a flexure curve at the wafer central portion. Denoted at 381 is a flexure curve at the wafer peripheral portion where the vacuum pressure is made properly lower than that at the wafer central portion and also the pin pitch made properly narrow. Denoted at 382 is a flexure curve corresponding to a conventional example wherein, while the vacuum pressure is held constant, the pin pitch is made appropriately narrower than that at the wafer central portion. In Figure 27B, denoted at 383, 384 and 345 are

distortion shapes of wafer distortions corresponding to the flexure curve 380, the flexure curve 381 and the flexure curve 382, respectively. --

Please substitute the paragraph beginning at page 76, line 2, and ending on page 77, line 4, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- It is seen from these drawings that, as regards the wafer distortion distribution shape, in the curves 382 and 385 of the conventional example, only in a narrow range a of the wafer position x, the shape is approximately registered. As compared therewith, in the curves 383 and 384 of this embodiment, in a wide range b which is about twice of the range a, the shape is approximately registered. Thus, the range for registration is widened. Although there remains a region, outside the range b, in which the shape is not registered, since at an outermost periphery of a wafer there is an invalid area of at least about 1 mm where no semiconductor device is formed, this does not cause a particular problem provided that the pin pitch is not greater than about 2mm. Since the wafer distortions produced at the wafer central portion and the peripheral portion can have substantially the same shape, as described above, if a chuck having the same pin disposition for every shot of a wafer to be exposed is used, it can be accomplished that a distortion of substantially the same distribution shape is produced in every shot. On that occasion, an image to be printed on every shot can be corrected in accordance with the distribution shape of the wafer distortion such as by driving or rotating an image lens or a reticle

by correcting the reticle pattern position beforehand. As a result, the overlay precision can be improved much more, throughout a wide range including the wafer peripheral portion. --

Please substitute the paragraph beginning at page 77, line 5, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- As regards the vacuum pressures at the wafer central portion and the peripheral portion, preferably they should be kept at a desired constant level without being influenced by a variation in atmospheric pressure, for example. To this end, a precision regulator, for example, may be used to supply a constant vacuum pressure, or the vacuum pressure may be detected and controlled to a constant level. Particularly, in this case, it is desirable since a good reproducibility of the wafer distortion distribution shape is assured thereby. --

Please substitute the paragraph beginning at page 77, line 16, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- It is to be noted that Figures 27A and 27B are based on the following equations according to material dynamics. First, the flexure curve 380 at the wafer central portion is given by:

$$v = [(P\cdot L^4)/(2\cdot E\cdot h^3)](x^2/L^2-2x^3/L^3+x^4/L^4) \qquad ...(2.62)$$ --

Please substitute the paragraph beginning at page 77, line 22, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- The flexure curves 381 and 382 at the wafer peripheral portion are given by:

$$v = [(Q \cdot R^4)/(4 \cdot E \cdot h^3)][-(R-x)/R+\{3 \cdot (R-x)^3/R^3\}-\{2 \cdot (R-x)^4/R^4] \qquad ...(2.63)$$

Here, for the curve 381, $Q = 0.85 \cdot P$ and $R = 0.87 \cdot L$. For the curve 382, $Q = P$ and $R = -0.83 \cdot L$. --

Please substitute the paragraph beginning at page 78, line 13, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- On the other hand, due to the influence of a polishing process during the wafer production or the influence of various processes during the semiconductor manufacture, there are cases wherein the periodicity of local warps on a wafer is different between the wafer central portion and the peripheral portion. When the periodicity at the peripheral portion is longer than that at the wafer central portion, the pin pitch at the wafer peripheral portion may be made wider than that at the wafer central portion. Also, the vacuum pressures may be set respectively and appropriately so as not to produce wafer distortion. By doing so, the contact rate at the wafer peripheral portion where a dust particle can be relatively easily adhered, can be lowered. --

Please substitute the paragraph beginning at page 79, line 1, and ending on page 80, line 16, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Further, although the free end faces of the pin-like protrusions constituting the wafer carrying and supporting surface have been explained as a super flat surface, depending on the actual processing precision, a very small tilt may be produced there. On that occasion, therefore,

the pitch of the pins which support the wafer may be exactly the same as the pin pitch L described hereinbefore. At the wafer central portion, in a worst case, for example as shown in Figure 22, the free end faces of the pins 310 and 336 may be tilted in opposite directions. On that occasion, the pitch of the points contacting the wafer becomes equal to Lx which is larger than the pin pitch L by an amount corresponding to the pin diameter. Thus, in this case, the wafer flatness and the distortion will become larger than V_1 and U_1 in equations (2.10) and (2.11). On the other hand, at the wafer peripheral portion, in a worst case, for example, as shown in Figure 23, the free end faces of the pins 313 and 314 may be tilted down toward the inside as illustrated. On that occasion, the pitch becomes equal to Ly which is larger than the pin pitch L by amount 1.5 times the pin diameter. Therefore, in this case, the wafer flatness and the wafer distortion become larger than V_2 and U_2 in equations (2.45) and (2.46). In order that the wafer distortion satisfies its tolerance throughout the whole surface, as described above, the remainder to be provided by subtracting a value 1.5 times the pin diameter from the pin pitch L determined as described above may be taken as the actual pin pitch. However, in that case, the pin-to-wafer contact rate increases accordingly, and it is undesirable. Therefore, it is effective to process and provide a flat surface without having a tilt that may cause and adverse influence, or to reduce the pin diameter as much as possible. Also, as shown in Figure 24, the free end face of the pin may be formed into a spherical shape. This is substantially equivalent to an example wherein the pin diameter is substantially equal to zero, and the contact rate can desirably be reduced very much. Further , the free end may be formed with a concave face without having a tilt, although the machining is not very easy. --

Please substitute the paragraph beginning at page 81, line 24, and ending on page 82, line 15, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Further, the right side of equation (2.69) above becomes smallest when the neutral plane correction coefficient $k = 1$, the smallest thickness $h = 0.625$ mm, the wafer flatness tolerance $dz = 80$ nm, and the largest wafer distortion tolerance dxdy - 5 nm. Then, $J \leq 0.005$. Namely, in order to satisfy the wafer flatness tolerance dz due to deformation inside the pin pitch, the wafer projection amount may be held to 5 mm or less. On that occasion, there occurs no problem, even in consideration of the diameter of the outermost pin 313, the outside shape tolerance of the wafer, the position precision of the same as placed on the chuck, and the width of the partition 312 when the same is provided outside the pin 313. Thus, the condition for correcting the wafer warp at the outer peripheral portion is more strict and, in this respect, the pin 313 at the outermost periphery of the chuck should desirably be disposed close to the outer periphery of the wafer as much as possible. --

Please substitute the paragraph beginning at page 82, line 16, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Although in the foregoing description the pin pitch of the chuck is explained as L and, at the wafer central portion and the peripheral portion, the chuck has a vacuum pressure P and a pin pitch L selected out of the above-described ranges, the pin pitch may of course be set separately and independently at the wafer central portion and the peripheral portion. Further, it is

not necessary that a uniform pitch be defined in the wafer central portion or in the wafer peripheral portion. As long as it is set to be within the above-described range, a non-uniform pin pitch may be used. --

Please substitute the paragraph beginning at page 83, line 1, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- The substrate to be held by the chuck is not limited to a Si wafer. For example, various substrates such as a gallium arsenic wafer, a composite adhesion wafer, a glass substrate, a liquid crystal panel substrate, and a reticle may be used. Further, as regards the outside shape thereof, it may not be circular, and it may have a rectangular shape, for example. On that occasion, the outside shape of the chuck may be changed in accordance with the outside shape of the substrate. --

Please substitute the paragraph beginning at page 83, line 20, and ending on page 84, line 6, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Although the chuck has been described with reference to a pin chuck, the present invention is applicable also to chucks having different shapes. For example, a ring-like chuck having concentric ring-like recesses (suction grooves) and concentric ring-like protrusions for defining a wafer supporting surface, which are alternately formed, may be used. On that occasion, the pitch of the ring-like protrusions in the radial direction may be regarded as the pin

pitch L. At the wafer central portion and the outer peripheral portion, a vacuum pressure P and a pin pitch L as have been described with reference to the embodiments may be set there. Substantially the same advantageous results are attainable with it. --

Please substitute the paragraph beginning at page 84, line 7, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- In accordance with the present invention, degradation of the wafer flatness and distortion due to flexure of a substrate inside the pin pitch as the same is held, can be reduced remarkably. Therefore, in the procedure for the manufacture of very fine devices, the defects of devices can be reduced and the yield rate can be improved significantly. --

Please substitute the paragraph beginning at page 86, line 27, and ending on page 87, line 4, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.

-- Figure 29 is a flow chart of a procedure for the manufacture of microdevices such as semiconductor chips (e.g., ICs or LSIs), liquid crystal panels, CCDs, thin film magnetic heads or micro-machines, for example. --

Please substitute the paragraph beginning at page 87, line 5, with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached in Appendix A.